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MECHANICAL CHARACTERIZATION OF USED JUTE FIBER PMC INFLUENCED WITH CHEMICAL TREATMENT

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ABSTRACT

The current work mainly focuses on identifying optimal chemical treatment for used jute, for treatment NaOH at three concentrations (20,30,40) with different treatment durations (20,40,60) considered. For post-treatment, three different types of chemicals (Alkaline, Kmno4, BenzylChloride) are taken for the study. The Taguchi technique is used to design the experiments and optimize the parameters. The results have shown that the tensile properties are better for UJE composite treated with 30% kmno4 and 60 min Treatment time, flexural properties are better for 40% kmno4 and 40min treatment time, impact properties for 30% Benzyl chloride and 40min treatment time these values are correlated with experimental results and shown good agreement.

KEYWORDS: Used Jute Fiber (UJE), Chemical Modification, Natural Fiber Composite, Taguchi & Optimization

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Original Article

1. INTRODUCTION

In a wide range of engineering applications, composites of Natural Polymers play an important role, because of their superior properties such as high strength to weight ratio, higher rigidity, and toughness. The matrix can be metal, ceramic, or polymer. The composite is named as polymer matrix composite (PMC) when the matrix is a polymer. The reinforcement stage can be either a fibrous or a non-fibrous process (particulates) of the natural world, or if its fibers come from plants or some other living species. They are known as Natural Fibers. The use of large quantities of composites, though, raises environmental concerns as a consequence of fibers used in the petroleum systems. Several studies have explored the use of natural fibers as binding materials for composites (Geethamma, Mathew, Lakshminarayanan, & Thomas, 1998)(Jústiz-Smith, Virgo, & Buchanan, 2008). In the automotive sector, natural fiber mats are used for internal and external parts. Such matt fabrics are thinner and less costly than glass fibers(Joshi, Drzal, Mohanty, & Arora, 2004).

Most of the researchers studies on natural fibers deal with the fundamental understanding of their behavior as composite reinforcement between fiber and matrix interfaces, chemical modifications in fiber surfaces(Reddy, Mohana Reddy, Mohan Reddy, & Reddy, 2018)(Kulkarni, Satyanarayana, Rohatgi, & Vijayan, 1983) (Gassan & Bledzki, 1999). All these studies include mainly natural fibers as reinforcement of manufactured composites. For less machine wear relative to synthetic fibers like nylon, coal, glass, these natural fibers have considerable cost and benefit. Demerits are not ideal for the absorption of moisture(Lackey, Vaughan, Inamdar, & Hancock, 2007).

Cellulose (58-63%), hemicelluloses, lignin, small protein (2%), and mineral matter (1%) have a chemical composition of jute fiber(Khan & Ahmad, 1996)at the weight. The major disadvantage of natural fibers is their low interface adhesion. The cellulose, hemicellulose, and lignin has been extracted from the surface of the fiber through chemical processes(Liu & Dai, 2007)performed an experimental analysis to improve the quality by NaOH-treated jute-mat and anhydride-grafted polypropylene (MPP) emulsion of Jute-propylene laminated composites (JPP).

The research results showed that the method of treatment improved interfacial shear stress and bending stress of composites dependent on polypropylene (PP). Saha et al. have examined the physicochemical properties of jute fibers processed under ambient or high-pressure steam conditions with NaOH solution(Shubhra et al., 2010). The results showed that the alkaline method could improve the jute fiber tensile strength of up to 65%. Mahjoub et al. investigated the effect on the tensile properties of kenaffibers of different alkaline treatment conditions with -respect to the amount of alkaline solution and time immersion(Mahjoub, Yatim, Mohd Sam, & Hashemi, 2014). The highest concentration of kenaffiber treatment has found in 5% alkaline water. Rokbi et al. researched the impact of alkalization of chemical processes on flex fiber(Rokbi, Osmani, Imad, & Benseddiq, 2011). The experimental results indicate that the bending behavior of alkali-treated fiber composites is better than that of non-treated fibers. The general trend indicates that each psychologist has minimized mechanical properties. The fiber layer should absorb wax, hemicelluloses, pectin, and other unidentified products for a stronger binding surface by these methods of alteration.

In the present research, the mechanical properties of the used woven jute fiber, which has been chemically treated using different NaOH solutions to strengthened the laminated composites of epoxy (UJE) has calculated. In order to modify the interfacial strength between used woven jute fiber(UJE) and matrix material, the UJE as retained in 20%, 30%, and 40% NaOH solution.

2. MATERIALS

2.1 Matrix

The Araldite LY 556 (Epoxy) and HY951(Hardener)in 10:1 ratio as a matrix, was supplied by Sree Industrial Composites, Hyderabad, India.

2.2 Fiber

Used Jute fibers were considered, which has been extracted from gunny bags available at local rice mills, bags are been taken from several bags to know the influence of fiber.

2.3 Chemicals

To identify the influence of chemicals three types of variations have taken, i.e., Sulphuric acid(H_2so_4), Benzoyl chloride, potassium permanganate($Kmno_4$)(Mohanta, 2016).

3. METHODOLOGY

The untreated Jute fiber mat has a moisture absorption tendency that improves moisture ability and fiber thickness. The bond between the fibers and the matrix is weak because of humidity, and the weight of hydrophobic matrices will be higher. The moisture content must be reduced by the pre-treatment of the Alkali treatment solution with NaOH(Sathishkumar, Suresh, Nagamadhu, & Krishna, 2017)

3.1 Pre-Treatment

In the pre-treatment stage, the fibers were soaked in methanol and Benzene in (1:1)ratio for 24 hours to remove wax, paint, and foreign contaminants.

3.2 Treatment

The weight loss of jute (fabrics) by the Alkali treatment it is observed that huge hemicelluloses content was dissolved. (Sathishkumar et al., 2017). It affected strengthening the fiber.

3.3 Post Treatment

To strengthen fiber, further treatment was done using with alkaline, benzoyl chloride, and permanganate solutions respectively. The different duration & treatments are as follows:

3.3.1 Alkaline Treatment

The Alkali treatment UJE mats were washed thoroughly & distilled water to remove any foreign matter/particle that adheres to the fiber surface. Then the UJF soaked in sulphuric acid for 1 min then again washed with distilled water and dried it for 24h.

3.3.2 Benzyl Chloride Treatment

To activate the cellulose and lignin hydroxyl groups, the fibers have initially treated with alkali, i.e., suspended for 1 hour in 10% NaOH, and then with continuous stirring for 15 min with benzyl chloride solution. The solution was then drained out, and the isolated fibers were soaked for 1 hour in ethanol to extract the chloride from the benzyl. Finally, the fibers are thoroughly washed with fresh water and dried in atmospheric air followed by 6 hours of oven temperature maintained at 70 ° C.

3.3.3 Permanganate Treatment

The fibers treated with pre NaOH have soaked with 0.05% of the Acetone in $KMnO_4$ for 1 min. Then the KMnO4 solution was drained, and the fibers dried up in the still air. The current work has been focused on optimization of chemical treatment with three parameters and three levels of Treatment time, concentration, and post-treatment process, as tabulated below in table 1.

Table 1: Taguchi Analysis Parameters

Sl. No.	Parameter	Level1	Level2	Level3
1	Post treatment chemicals	H_2SO_4	$KMNO_4$	BENZYL
2	Treatment time	20	40	60
3	NaOH concentration for treatment	20	30	40

For Sample Preparation, Hand layup technique was adopted for the making of composite specimens, as per the ASTM standards D790, six sets of specimens prepared and tested for each sample. 150*150*5 mm^3mold has prepared for making composites mold release spray was been used for easy release of the casted plate. The required dimensions were marked and sized the plate with the help of a laser jet cutting machine.

4. EXPERIMENTAL

Taguchi technique in the design of experiments is used for a Combination of chemical treatments to be carried to fabricate

UJE Composite. Taguchi Technique with three parameters chemicals, Treatment Time, Concentration for each parameter three levels taken. For three input parameters and three levels of each, L9 orthogonal array was best suitable as shown in Table 2.

Table 2: Shows the Orthogonal Array of L9 with Parameters of 3 Levels

Sl. No	Chemicals	Treatment time	Concentration	Sample Tag
1	H_2SO_4	20	20	20N20H
2	H_2SO_4	40	30	30N40H
3	H_2SO_4	60	40	40N60H
4	$KMNO_4$	20	30	30N20K
5	$KMNO_4$	40	40	40N40K
6	$KMNO_4$	60	20	20N60K
7	BENZYOL	20	40	40N20B
8	BENZYOL	40	20	20N40B
9	BENZYOL	60	30	30N60B

(a) Sample Tagging

All the specimens are tagged with different codes of 8 letters, for example, a tensile test sample tagged as 40N60H-T. In that first two letters indicates the percentage of concentration used for treatment, third letter N indicates as NaOH, fourth and fifth letters indicate Treatment time, 6^{th} letter is for post-treatment chemical, in this case, it is H for H_2SO_4 and dash to separate type of test. Here T is for Tensile Test. As shown in table 3

Table 3: Shows the Sample Tagging

1	2	3	4	5	6	7	8
4	0	N	6	0	H	-	T

4.1 Tensile Test

The composite specimens with 150 mm long, 20 mm wide, 5 mm thickness were prepared according to the ASTM D638 M standards for investigating Tensile Behavior. Samples were tested using a universal testing machine (Instron-3369) at G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, with a crosshead speed of 2.5 mm/min.

4.2 Flexural Test

To measure flexural properties, three-point bend tests were performed in compliance with ASTM D 790M. The samples were 127 mm long, 13 mm wide, and 5 mm thick, respectively. The exterior rollers were 64 mm apart in a three-point bending test and samples were tested at a pressure of 0.2 mm / min. The choice was made for a three-point bending test, as it needs minimal material for each test and eliminates the need to measure center points deflections with the test equipment accurately. The specimens were tested at the same crosshead speed by the same testing machine. The composite flexural strength (σ) was determined using the following relation.

$$\sigma = \frac{3PL}{2bt^2}$$

Where L is the length (64 mm) of the support span, b is width: t is thickness; P is the maximum load

4.3 Impact Test

The impact test of UJE composites prepared according to ASTM D256. A tool for the evaluation of composite materials ' strength and flexibility. The coated test sample breached by the impact of a giant pendulum or hammer, which falls through a fixed distance at a specified rate. The test measures the energy that the broken specimen absorbs.

(b) Optimization

The Taguchi method is used to optimize the input parameters. Based on mean effective plots, the optimum levels of parameters are to be identified. The present study makes a novel approach of applying a Taguchi method for constituents optimization in a material to achieve required Mechanical properties, i.e., flexural strength, Tensile strength, Impact strength. As the work intended to maximize the flexural strength larger was the better method adopted for optimization (Vardhan, 2018).

(c) Testing and Validation

There are twenty-seven different tests to be carried to determine optimal combination of parameters, by using Taguchi technique number of tests are reduced to nine in a specified orthogonal table value using the test factor combinations The optimal combination of input parameters given by Taguchi methods were verified by preparing six sets of new samples with optimal combination of parameters and were then tested as per ASTM standard. The results obtained were compared with system results as tabulated in table 4.

Table 4: Shows the Properties of Chemically Treated Fibers

Chemical	Treatment time	Concentration	Tensile Strength (MPa)	Snra T	Mean T	Flexural Strength (MPa)	Snra F	Mean F	Impact Strength (MPa)	Snra I	Mean I
Alkaline	20	20	49.39	33.87	49.39	135.2	42.61	135.2	1.9	5.57	1.9
Alkaline	40	30	52.36	34.37	52.36	142.3	43.06	142.3	2.2	6.84	2.2
Alkaline	60	40	69.19	36.80	69.19	141.01	42.98	141.01	1.6	4.08	1.6
Kmno4	20	30	92.13	39.28	92.13	142.35	43.06	142.35	1.8	5.10	1.8
Kmno4	40	40	86.35	38.72	86.35	162.35	44.20	162.35	2.6	8.29	2.6
Kmno4	60	20	73.63	37.34	73.63	156.23	43.87	156.23	2.4	7.604	2.4
benzoyl	20	40	70.28	36.93	70.28	122.3	41.74	122.3	1.92	5.66	1.92
benzoyl	40	20	79.61	38.01	79.61	133.25	42.49	133.25	2.1	6.44	2.1
benzoyl	60	30	94.26	39.48	94.26	138.12	42.80	138.12	2.9	9.24	2.9

5. RESULTS AND DISCUSSIONS

5.1 Tensile Strength

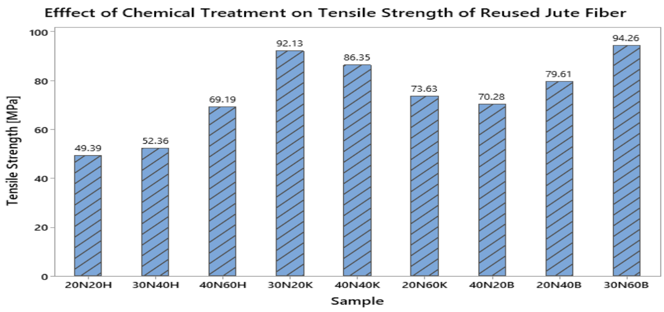

Figure 1: Shows the Tensile Properties of Chemically Treated UJE.

From the following Figure 1, the effect of chemical treatment on Tensile strength of used Jute fiber (UJE) to

evaluate the value, 9 sets of experiments are carried as designed the experiments by using using Taguchi method. From the tests, it shows that maximum tensile value for 30N60B specimen and 30N20K & 30N60B are almost close together.

The sample 30N60B- 30% of NaOH concentration for treatment of fibers then followed by 60 min Benzyl chloride. The sample 30N20K-30% of NaOH concentration for treatment of fibers then followed by 20 min Potassium permanganate.

All the Tensile strength responses are given as inputs to determine the optimal parameter.

Table 5: Response Table for Means Tensile Strength

Level	Chemical	Treatment Time	Concentration
1	56.98	70.60	67.54
2	81.38	72.77	79.58
3	84.04	79.03	75.27
Delta	27.06	8.43	12.04
Rank	1	3	2

Table 5 shows the highest value of the max-min of a mean of means is 27.06, indicating that the parameter $KMnO_4$ most influences the fiber tensile strength. Concentration is the second parameter (12.04) and treatment time (8.43) is the third.$KMnO_4$, concentration and treatment time above the optimal limit, resulting in a significantly higher rate of decomposition and instability the fiber.

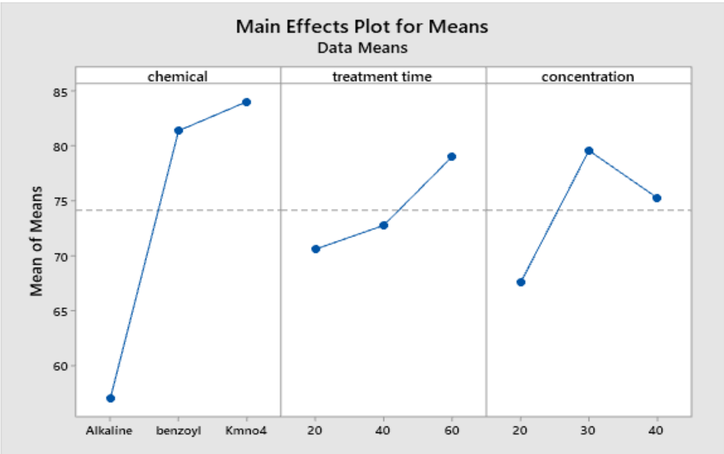

Figure 2: Effect of Process Parameters on UJE.

The above figure 2 of the main effects plot for means, the chemical and concentration staring in the most significant role for tensile strength in the last treatment time. The post-treatment with $KMnO_4$ is showing as an optimal parameter level for pre-treated jute fibers for maximum tensile strength with 30% of NaOH for treatment to strengthen the fibers for a time of 60 min as shown in Table 6.:

Table 6: Optimal Parameters of UJE for Tensile Strength

Sl. No	Parameter	Optimal Level
1	Chemical	$KMnO_4$
2	Treatment Time	60 min
3	Concentration	30% of NaOH

For any material application, its strength should be optimal/maximum. In this connection to get the maximum value of tensile strength, Flexural strength, and Impact strength larger, the better is taken for optimal level calculation from the S-N ratio by using the following relation in the mini tab.

S/N ratio $= -10 \log(\frac{1}{n} \sum_{i=1}^{n} y_i{}^{k})$

All the numerical values are tabulated to determine the significant parameter in the Table 6, the rank evaluated based on the difference between the average of means of concern level.

Sample calculation for significant parameter(CHEMICAL)

$$\text{Level1} = \frac{49.39+52.36+69.19}{3} = 56.98$$

$$\text{Level2} = \frac{70.28+79.61+94.26}{3} = 81.38$$

$$\text{Level3} = \frac{92.13+86.35+73.63}{3} = 84.04$$

As per optimal parameter value suggested by Taguchi from Table 6, the specimens were prepared and tested the value obtained tensile strength is 96MPa.

5.2 Flexural Strength

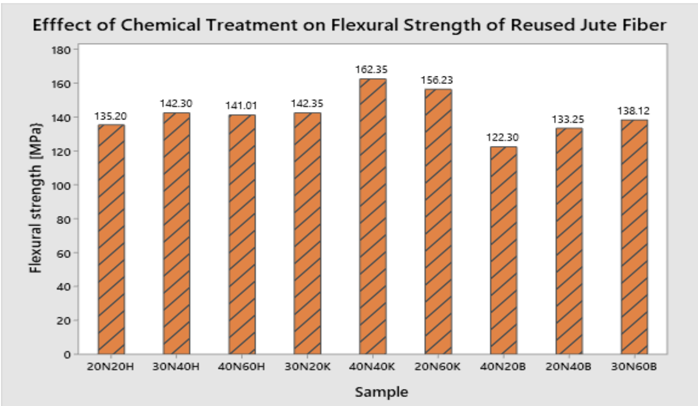

Figure 3: Shows the Flexural Properties of UJE.

From the above figure 3, the effect of chemical treatment on Flexural strength of used Jute fiber(UJE) to evaluate the value, 9 sets of experiments are carried as designed the experiments by using Taguchi method. From the tests, it shows that maximum Flexural value for 40N40K specimen and 20N60K is also close to the value of 40N40K. The sample 40N60K- 40% of NaOH concentration for treatment of fibers then followed by 60 min Pottasium permanganate. The sample 20N60K-20% of NaOH concentration for treatment of fibers then followed by 60 min Potassium permanganate.

All the Flexural strength responses are given as inputs to determine the optimal parameter. The following table.7 shows the Means of Flexural strength

Table 7: Response Table for Means Flexural Strength

Level	Chemical	Treatment Time	Concentration
1	139.5	133.3	141.6
2	131.2	146.0	140.9
3	153.6	145.1	141.9
Delta	22.4	12.7	1.0
Rank	1	2	3

Table 7 shows the highest value of the max-min of the mean (22.4) indicates that the

Flexural strength is most affected by the $KMnO_4$ parameter. Treatment time is second parameter (12.7), Concentration (1.0) is the third. KMNo4, concentration, and treatment time above the optimal limit, resulting in a significantly higher rate of decomposition and unstable the fiber.

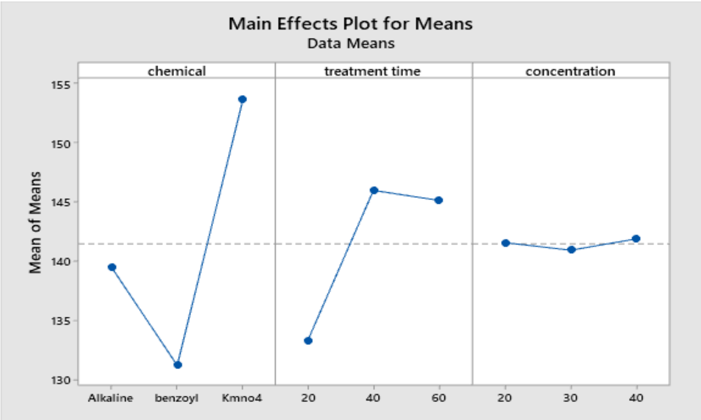

Figure 4: Effect of Process Parameters on UJE.

From figure 4 main effects plot for means, the chemical and Treatment time staring in the most significant role for Flexural strength and last Concentration. The post-treatment with $Kmno_4$ is showing as an optimal parameter level for pre-treated jute fibers for maximum Flexural strength with 40% of NaOH for treatment to strengthen the fibers after a time of 40 min as shown in table 8.

Table 8: Optimal Parameters for UJE for Flexural Strength

Sl. No	Parameter	Optimal Level
1	Chemical	$KMnO_4$
2	Treatment Time	40 min
3	Concentration	40% of NaOH

All the numerical values are tabulated to determine the significant parameter in the Table 8. The rank was evaluated based on the difference between the average of means of concern level.

Sample calculation for a significant parameter (Treatment Time)

$$\text{Level1} = \frac{135.2+142.35+122.3}{3} = 133.3$$

$$\text{Level2} = \frac{142.3+162.35+133.25}{3} = 146.0$$

$$\text{Level3} = \frac{141.01+156.23+138.12}{3} = 145.1$$

As per optimal parameter value suggested by Taguchi from table no, the specimens were prepared and tested the value obtained Flexural strength is 162.35 MPa

5.3 Impact Test

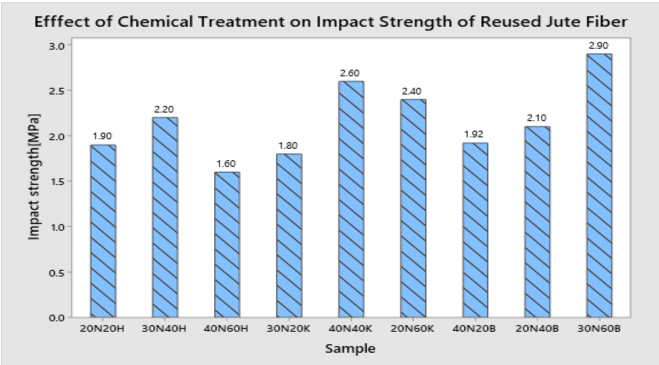

Figure 5: Shows the Impact Properties of UJE.

From the above figure 5, the effect of chemical treatment on Impact strength of used Jute fiber(UJE) to evaluate the value, 9 sets of experiments are carried as designed of the experiments by using Taguchi method. From experimental results shown that maximum Impact value for 30N60B specimen and 40N40K is also nearer to the value of 30N60B.The sample 30N60B - 30% of NaOH concentration for treatment of fibers then followed by 60 min Benzyl Chloride. The sample 40N40K -40% of NaOH concentration for treatment of fibers then followed by 40 min Potassium permanganate.

All the Impact strength responses are given as inputs to determine the optimal parameter.

Table 9: Response Table for Means Impact Strength

Level	Chemical	Treatment Time	Concentration
1	1.900	1.873	2.133
2	2.307	2.300	2.300
3	2.267	2.300	2.040
Delta	0.407	0.427	0.260
Rank	2	1	3

Table 9 shows the highest value of the max-min of the mean of means is 0.427 indicating, that the parameter Treatment Time most influences the fiber Impact strength. Chemical is the second parameter (0.407), and Concentration(0.26) is the third $KMnO_4$, concentration, and treatment time above the optimal limit, resulting in a significantly higher rate of decomposition and unstable the fiber.

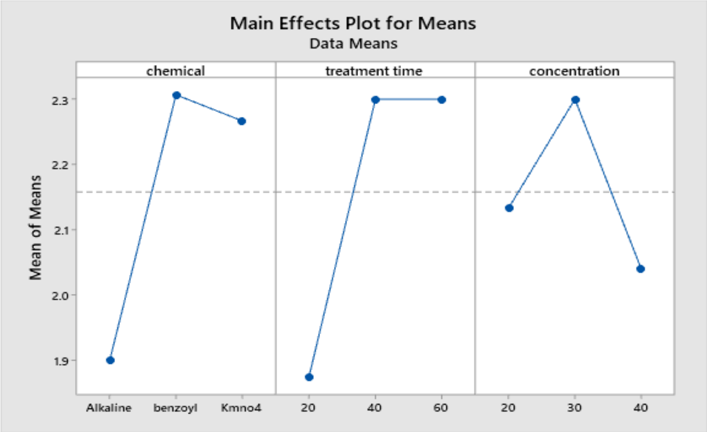

Figure 6: Effect of Process Parameters on UJE.

From figure 6 main effects plot for means, the chemical and Treatment time staring in the most significant role for Impact strength and last Concentration. The post-treatment with Benzyl chlorides showing as an optimal parameter level for pre-treated jute fibers for maximum Impact strength with 30% of NaOH for treatment to strengthen the fibers after a time of 40 min as shown in the table 10.

Table 10: Optimal Parameters for UJE Impact Strength

Sl. No	Parameter	Optimal Level
1	Chemical	Benzyl Chloride
2	Treatment Time	40 min
3	Concentration	30% of NaOH

All the numerical values are tabulated to determine the significant parameter in the table 10 the rank evaluated based on the difference between the average of means of concern level.

Sample calculation for significant parameter(Concentration)

$$\text{Level1} = \frac{1.9+2.4+2.1}{3} = 2.13$$

$$\text{Level2} = \frac{2.2+1.8+2.9}{3} = 2.30$$

$$\text{Level3} = \frac{1.6+2.6+1.92}{3} = 2.13$$

As per optimal parameter value suggested by Taguchi from Table 10, the specimens were prepared and tested the value obtained. Impact strength is 2.8 MPa

6. CONCLUSIONS

Taguchi method was applied to design the experiments and to investigate the influence of various parameters (Chemicals, Concentration, Treatment time) on the mechanical properties. The following conclusions are obtained from experimental results:

- Taguchi method provided simple, efficient methodology in optimizing the optimal parameters for chemically treated used jute fiber.
- The post-treatment with $KMNO_4$ shows that the pre-treated jute fibers have the optimal parameter level for maximum tensile strength, with 30% of NaOH to strengthen the fibers for 60 min.
- The post-treatment with $KMNO_4$ shows that the pre-treated jute fibers have the optimal parameter level for maximum Flexural strength, with 40% of NaOH to strengthen the fibers for 40 min.
- The post-treatment with Benzyl chloride shows that the pre-treated jute fibers have the optimal parameter level for maximum impact strength, with 30% of NaOH to strengthen the fibers for 40 min.

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